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Review

Pterocarpus santalinus Linn. f. (Rath handun): A Review of Its Botany, Uses, Phytochemistry and Pharmacology

Kodithuwakku Kankanange Indika Upali Arunakumara[1], Buddhi Charana Walpola[2]*, Siripala Subasinghe[1], and Min-Ho Yoon[3]*

[1]*Department of Crop Science,* [2]*Department of Soil Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*

[3]*Department of Bio-Environmental Chemistry, College of Agriculture and Life Sciences, Chungnam National University, Daejeon, 305-764, Republic of Korea*

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***Pterocarpus santalinus* Linn.f., commonly known as Red sanders, belongs to the family Fabaceae. It is endemic to India and considered globally endangered, with illegal harvest being a key threat. The plant is renowned for its characteristic timber of exquisite color, beauty, and superlative technical qualities. The red wood yields a natural dye santalin, which is used in coloring pharmaceutical preparations and foodstuffs. In the traditional system of medicine, the decoction prepared from the heartwood is attributed various medicinal properties. It has been used in inducing vomiting and treating eye diseases, mental aberrations, and ulcers. The heartwood of Red sanders is known to have antipyretic, anti-inflammatory, anthelmintic, tonic, hemorrhage, dysentery, aphrodisiac, and diaphoretic activities. It has also been used as a cooling agent. Ethanol extract of stem bark was reported to possess anti-hyperglycaemic activity. The wood in combination with other drugs is also prescribed for snake bites and scorpion stings. Phytochemical investigations of aqueous and ethanol extracts of stem bark revealed the presence of alkaloids, phenols, saponins, glycosides, flavonoides, triterpenoides, sterols, and tannins. The heart wood contains isoflavone glucosides and two anti-tumour lignans, viz., savinin and calocedrin. However, the species has remained unexplored for many pharmacological activities claimed. The present paper reviewed botany, uses, phytochemistry, and pharmacology of *P. santalinus*.**

Key words: pharmaceutical preparations, *Pterocarpus santalinus*, traditional medicine

Medicinal plants are plants containing inherent active ingredients used to cure disease or relieve pain [Okigbo *et al.,* 2008]. The use of traditional medicines and medicinal plants in most developing countries as therapeutic agents for the maintenance of good health has often been reported. The World Health Organization estimated that 80% of the populations of developing countries rely on traditional medicines, mostly plant drugs, for their primary health care needs. Medicinal plants are an important element of the indigenous medical systems in Sri Lanka, where about 35% of the population, even now, depends on traditional systems of medical care [Smith *et al.,* 2006]. The Sri Lankans appeared to have developed a system whereby they select and continue to use plants that they find the most effective for health care purposes. Ayurvedic physicians and traditional practitioners of medicines are a part of the Sri Lankan society, and there is an interwoven relationship between the communities and such practitioners. In the rural areas, people collect their requirements of medicinal plants from forests, and communities practiced sustainable concepts, with minimal damage to the habitats in which these precious plants are found. Out of 1,414 medicinal plant species available in Sri Lanka, about 250 species are commonly used, while 50 species are heavily used [Pushpakumara *et al*., 2002]. Nearly 80 medicinal plant species are now considered threatened. *Pterocarpus santalinus* is among the threatened species due to over exploitation without commensurate replacement of natural stands. The species is endemic to

*Corresponding author
Phone: +82-42-821-6733; Fax: +82-42-823-9241
E-mail: mhyoon@cnu.ac.kr (Min-Ho Yoon)
Phone:+82-42-821-7888; Fax:+82-42-823-9241
E-mail: buddhiwalpola@yahoo.com (Buddhi Charana Walpola)

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India and considered globally endangered, with illegal harvest being a key threat. Though the species has an increasing demand, commercial exploitation is yet to be started due to lack of reliable information on various aspects of the plant. The present paper reviews botany, uses, phytochemistry, and pharmacology of Rath handun (*P. santalinus* Linn. f.).

Geogrophical Distribution of *P. santalinus*

Pterocarpus species (*Pterocarpus dalbergioides, Pterocarpus indicus, Pterocarpus marsupium,* and *P. santalinus*) are widely distributed in the tropics throughout the world [Rao and Raju, 2002] especially India, Sri Lanka, China, and Taiwan [Rudd, 1991]. However, wild status of these species still needs verification. Though distribution of *P. santalinus* is believed to be restricted to India, Poudel [2003] reported that some parts of the vegetation in Tara hill of Kascki district in Nepal is dominated by this species. Reports of exports from Cambodia (30 m^3 of timber in 1999), Madagascar (20 m^3 timber in 2000), and Mexico (one unit of carvings and one unit of wood chips in 1998) have been made; however, it seems likely that these countries were mis-reporting or re-exports rather than exports. The species *Pterocarpus* is considered to be rare in Sri Lanka, where its natural habitats are constantly under human pressure. The *P. santalinus* population in Sri Lanka is limited to several plants, of which most can be found in Southern part of the country, in particular, in Matara district. The species is a strong light demander and does not tolerate overhead shade. It also cannot withstand water-logged conditions [Rao and Raju, 2002]. Physiographically, the most favorable altitude for *P. santalinus* is between 300 and 800 m, and grows on hilly terrain and slopes with very shallow to shallow brown, sandy loam or bouldery soils of a friable nature [Raju and Nagaraju, 1998].

VERNACULAR NAMES

Hindi - Lal chandan, Rakta-chandan

Kannaga - Agaru, Honne

Malayalam - Patrangam, Tilaparnni

Marathi - Tambada chandana

Sanksrit - Rakta chandana

Tamil - Ratha sandanam, Chenkunkumam, Sivappu chandanam, Sandana vengai

Telugu - Agaru gandhami, Yerra chandanamu, Rakta chandanamu [Ravikumar and Ved, 2000].

Fig. 1. Mature *P. santalinus* (Red sandal) plant.

Botanical Description

P. santalinus Linn. f., belonging to family Fabaceae, is a small to medium sized deciduous tree, with an extremely hard, dark purple heart-wood with a bitter flavor [Dhanabal, 2007]. Bark is blackish brown, 1-1.5 cm thick and deeply cleft into rectangular plates by deep vertical and horizontal cracks (Fig. 1). Blaze is pale yellow with numerous pink streaks exuding copious red sticky thick gum. Branchlets are drooping and hairless. Leaves are 3 foliated, 10-18 cm long and rachis swollen at base. Generally, there are 3 leaflets (rarely more than 3), broadly egg-shaped or orbicular. Base is round or slightly heart-shaped. Apex is also rounded or deeply notched. Margin is entire, leathery, shiny, hairless, and distinctly stalked. Flowers are bisexual, stalked in auxiliary simple or sparingly branched racemes, yellow, about 2 cm long, fragrant. Pods are unequally orbicular, flat about 5×4.5 cm including the wing, and gradually narrow into a short tip about 1-cm long. Seeds 1 or rarely 2, more or less kidney shaped, 1-1.5 cm long, smooth, reddish brown.

Natural Regeneration and Propagation

Though a mature plant produces thousands of flowers in a season, the natural fruit set of *P. santalinus* is very low due to several reasons. This tree is able to fruit through both self- and cross-pollination, thus initiates

more fruit production, but gradually and selectively eliminates the growing weak offsprings, especially those resulting from self-pollination. The compatibility to self-pollen seems to provide fertility assurance in the event of failure of outcrossing. Furthermore, the species is expected to maintain lower levels of variation due to its endemic status with restricted population size, and consequently reduces opportunities for outcrossing. The species has been considered to be endangered due to constant human or other pressures, and any reduction in the population size is bound to enforce inbreeding and genetic bottlenecks. Thirdly, low maternal energy investment is available during the dry period for the rapidly growing offsprings. These factors could be collectively responsible for the low natural fruit set rate [Purnachandra Rao and Solomon Raju, 2002]. The pollination ecology of *P. santalinus* is vulnerable to dry and hot conditions. The flowers remain unvisited all day long due to the absence of pollinator activity. The natural fruit set is a consequence of pollinator activity during moonlit night and early morning hours. The self-compatibility through geitonogamy is virtually inevitable for the species to produce fruits in situations when pollinators are scarce. Most of the endemic and endangered plant species have been reported to be self compatible through geitonomy and this selfing ability is expected to be a 'fail-safe' strategy to produce fruits when pollinators are scarce [Anderson *et al.,* 2001; Neel, 2002]. Geitonomy also exists in *P. santalinus*. However, the dominant cross-pollinating nature of the species exhibits facultative xenogamous breeding system. This breeding system is favorable for *P. santalinus* as an endemic and endangered species to ensure continued survival [Purnachandra Rao and Solomon Raju, 2002]. Under Sri Lankan conditions, the regeneration capacity of the species is also poor due to poor seed germination. It has been reported that conventional vegetative propagation techniques such as grafting and air-layering have limited scope in large-scale multiplication of this species, and rooting of cuttings was also found to be poor [Rajeswari and Paliwal, 2008]. Investigations on the success of vegetative propagation under Sri Lankan conditions have also reported similar results. However, according to Rajeswari and Paliwal [2008], the *in vitro* propagation of the species was successful and no significant growth differences were found between seedlings and *in vitro* propagated plants (Fig. 2). Cultivation of *P. santalinus* has been reported; however, the success of plantations is yet unknown. Commonly the species is planted as monoculture and as an ornament. Large quantities of extracts ,from artificially propagated sources have been exported. Reliable evidence of trade in wild-sourced wood is lacking; however illegal exports are suspected based on evidence of seizures.

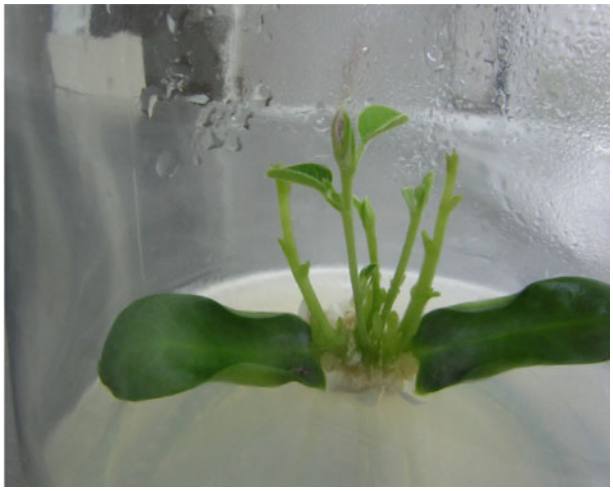

Fig. 2. *In vitro* propagation of *P. santalinus.*

Uses

P. santalinus is a highly impressive indigenous herb [Shoba *et al.,* 2007], thus researches during the past two decades have shown a renewed interest [Gupta *et al*., 1998; Kwon *et al.,* 2006]. The heartwood is rubbed with water, honey, ghee, and oil, applied as collyrium to alleviate defects of vision. It is also used for treating skin diseases, bone fracture, leprosy, spider poisoning, scorpion-sting, hiccough, ulcers, general debility, and metal aberrations [Arokiyaraj *et al*., 2008]. Wood paste is applied on boils and other skin eruptions, infections, inflammation, and on forehead to relieve headache. Decoction of fruits is used to cure chronic dysentery, and by Kani tribes to check dermatological conditions including psoriasis. Wood and bark brew taken orally relieves chronic dysentery, worms, blood vomiting, weak vision, and hallucination. Wood powder is used to control hemorrhage, bleeding piles, and inflammation. The antibacterial, anticancer, hepatoprotective, and wound healing properties of this drug have been established recently. The wood of *P. santalinus* is highly valued for the manufacture of furniture, musical instruments, cosmetics, dye, and for medicinal purposes. Japan has been identified as the main market for the wood of this species outside of India.

Phytochemistry

The qualitative phytochemical analysis of *P. santalinus* confirmed the presence of various components, such as carbohydrates, steroids, anthocyanins, saponins, tannins,

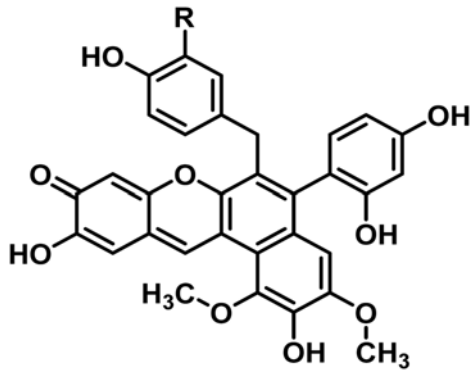

Fig. 3. Chemical structure of santalin (R=OH, santalin A; R=OCH_3, santalin B).

phenols, triterpenoids, flavonoids, glycosides, and glycerides [Narayan *et al.,* 2007]. In fact, *Pterocarpus* species are found to be rich in isoflavonoids, terpenoids, and related phenolic compounds, β-sitosterol, lupeol, (-) epicatechin. [Kesari *et al*., 2004]. In addition auron glycosides viz., 6-OH-1-methyl-3',4',5'-trimethoxyaurone-4-*O*-rhamnoside and 6,4'-dihyroxyaurone-4-*O*-neohesperidoside, and isoflavone glycoside 4',5-dihydroxy 7-methyl isoflavone 3'-*O*-beta-D-glucoside are also present in *P. santalinus* [Krishnaveni and Sirinivasa Rao, 2000a] (Fig. 3). Yoganarasimhan *et al.* [2003] also observed pterocarpol, santalins A and B, pterocarptriol, ispterocarpolone, pterocarpo-diolones with β-eudeslol and cryptomeridol in heartwood. Ether, alkalis, and three other crystalline principles santal, pterocarpin, homopterocarpin, small quantity of tannin, and kino-tannic acid have also been found in the wood [Krishnaveni and Sirinivasa Rao, 2000a; Cho *et al.,* 2001]. Triterpene is reported to be present in the callus of stem cuttings [Krishnaveni and Sirinivasa Rao, 2000b]. The leaves of this plant contain methanol [Arokiyaraj *et al.,* 2008], and ethanol can be extracted from stem bark [Kameswara Rao *et al.*, 2001].

Pharmacology

As can be found in ethno-botanical reports, a number of plants are reputed in the indigenous system of medicine for their antidiabetic activities [Kameswara Rao *et al.,* 2006; Mukherjee *et al.,* 2006], however, many of them remain to be scientifically established [Jayakar and Suresh, 2003]. *P. santalinus* is one of such plants used for treatment of diabetes [Kameswara Rao *et al.,* 2006; Mukherjee *et al.,* 2006]. Cups made up with *P. santalinus* woods have traditionally been used for drinking water as a treatment of diabetes [Nagaraju and Rao, 1989; Nagaraju *et al*., 1991; Thammanna *et al.,* 1994; Latheef *et al.,* 2008]. In addition to diabetes mellitus and related symptoms, *P. santalinus* is useful in treating bilious affections, skin diseases such as antihelmintic, aphrodisiac, and alexiteric as well as vomiting, thirst, eye diseases, ulcers, and diseases of the blood [Kirtikar and Basu, 2001; Latheef *et al.,* 2008]. Infusion of the decoction of the fruit is used as astringent tonic in chronic dysentery [Kondeti *et al.,* 2010]. Stem bark powder with soft porridge has been used in treating diarrhea and the paste of the wood has been considered as a cooling agent for external application treating inflammations and headache, mental aberrations, and ulcers [Krishnaveni and Sirinivasa Rao, 2000c]. The lignan isolated from the heartwood is known to inhibit tumor necrosis factor alpha production and T-cell proliferation [Krishnaveni and Sirinivasa Rao, 2000c; Cho *et al.,* 2001]. The aurone glycosides isolated from heartwood have been reported to exhibit antiplasmodial activity [Kayser *et al*., 2001] and has been used as a potential antileishmanial drug [Kayser *et al.*, 1998]. Methanol and aqueous extracts of heartwood have shown antihepatotoxicity in CCl_4-induced hepatoxicity [Rane and Gramarc, 1998]. Himoliv, a polyherbal ayurvedic formulation containing *P. santalinus* as one of the ingredients has been reported to possess hepatoprotective activity [Bhattacharya *et al.,* 2003]. The stem bark extract was shown to contain maximum activity against *Enterobacter aerogenes, Alcaligenes faecalis, Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris, Bacillus cereus, Bacillus subtilis,* and *Staphylococcus aureus* [Manjunatha, 2006]. Ethanolic stem bark extract is known to possess antihyperglycemic activity [Kameswara Rao *et al*., 2001]. The leaf extract also showed maximum activity against *E. coli, A. faecalis, E. aerogenes,* and *P. aeruginosa* [Manjunatha, 2006].

Studies with Animal Models

Decoction of the heartwood has been reported as a depressant and was also shown to have anti-inflammatory activity for induced hind paw edema in rats when prepared in formalin (3%). In addition, the bark extract has a blood glucose level-lowering effect in experimental animals [Varma and Vijayamma, 1991; Rao *et al.,* 2001]. The ethanol extracts of *P. santalinus* at doses of 50-250 mg/kg showed gastroprotective effect in reserpine-induced, pyloric-ligated experimental rates [Narayan *et al.,* 2007]. Dhanabal *et al.* [2007] and Manjunatha [2006] investigated the *in vivo* anti-hepatotoxic effects of the chloroform extract of the heartwood of *P. santalinus* using rats. The phytochemical investigation of the tested extract demonstrated the presence of alkaloids, flavonoids, and triterpenoids. Hence, the hepatoprotective activity of *P. santalinus* may be correlated to its components including alkaloid, triterpenoid, saponins, and flavonoidal

constituentst [Baek *et al.,* 1996; Metha *et al.,*1999; Tran *et al.,* 2001; Vijayan *et al.,* 2003; Xiong *et al.,* 2003; Dhanabal *et al.,* 2007]. Vinay Kumar *et al.* [2010] investigated the effect of bark of *P. santalinus* on blood glucose, plasma insulin, and serum lipids, and the activities of hepatic glucose metabolizing enzymes in streptozotocin induced diabetic rats. According to their results, the active fraction [ethyl acetate: methanol (9:1) fraction] of ethanolic extract of the *P. santalinus* bark possess the anti-hyperglycemic and anti-hyperlipidemic active principles, which act by improving insulin secretion and alterations in the carbohydrate and lipid metabolisms. The increased activities of gluconeogenic enzymes were shown to be reduced after treatment with other medicinal plants [Maiti *et al.,* 2004; Pari and Amarnath Satheesh, 2004; Pushparaj *et al.,* 2007], in experimental diabetic animals, and these results are also comparable with those of Vinay Kumar *et al*. [2010]. Kameswara Rao *et al.* [2001] examined the effect of oral administration of different doses of *P. santalinus* bark extracts in normal and diabetic rats on blood glucose levels. In this study ethanolic extract of bark of *P. santalinus* (0.25 g/kg) did not show hypoglycemic activity in normal rats. The same ethanolic extract showed the maximum hypoglycemic activity (58.5%) in diabetic rats after 7 h of treatment, whereas Nagaraju *et al.* [1991] showed hypoglycemic activity with ethanolic fractions of *P. santalinus* wood in both normal and diabetic rats on treatment. The ethanolic fraction of *P. santalinus* bark showed more marked antihyperglycemic activity than the other fractions.

Conclusion

The increased demand has placed a great strain on the natural populations of *P. santalinus*. Collectors of medicinal plants are resorting to unsustainable exploitation causing serious threat to the survival of the species. Thus, the species is reported to show a poor regeneration capacity. Cultivation in a substantially high scale is yet to be started. Therefore, there is a need to conserve the species for the benefit of mankind. More importantly, critical elements of effective conservation strategies need to be discussed.

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